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Levingston

TECHNOLOGY TRANSFER PROGRAM (TTP)

FINAL REPORT

STANDARDS

# STANDARDS
# EXECUTIVE SUMMARY

Prepared by:

Levingston Shipbuilding Company
in conjunction with:
IHI Marine Technology, Inc.

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# PREFACE

This document is a summary of a report on Standards resulting from the Shipbuilding Technology Transfer Program performed by Levingston Shipbuilding Company (LSCO) under a cost-sharing contract with the U. S. Maritime Administration.

This summary provides a condensation of the findings and conclusions of Levingston's study of the practices currently in use in the shipyards of Ishikawajima-Harima Heavy Industries Co., (IHI), of Japan0. Levingston gratefully acknowledges the generous assistance of the IHI consulting personnel and of all the IHI personnel in Japan who made this study possible.

For details concerning the Technology Transfer Program or of the information contained herein, please refer to the full Final Report on this subject.

# EXECUTIVE SUMMARY

## INTRODUCTION

### PURPOSE AND SCOPE

The purpose of this study was to analyze the Japanese (IHI) concept of Standards and their application in the actual working environment in IHI shipyards. As in the many other areas of study within the Technology Transfer Program (TTP), the objective of the study was to define possible beneficial and cost-saving elements or methodologies which could be instituted in Levingston and in other medium-size shipyards in the United States.

### PRINCIPLES OF STANDARDIZATION

Everyone today recognizes the values of standardization. Virtually every handbook or textbook on manufacturing systems contains a chapter or section on standardization and the benefits that result therefrom. This study revealed no new technology, but like other repcrts in this series, it does reveal a superior achievement in the application of known standardization techniques and methods within the marine industry.

IHI’s philosophy is that any large scale standardization effort must begin in the design stage. Because the associated manufacturing facilities already exist, standardization of design must be accomplished in harmony with production limitations and capabilities.

From standardization of the product, the effort expands. Material is coded, vendors selected, material purchased, production plans determined, and schedules set. For each activity, hundreds of pieces of information pass through the system. The opportunity to reduce the amount of data handled at every level in the manufacturing process depends directly on the extent of standardization. Reduction in data handled also reduces the occurrence of errors and misunderstandings.

Standardization of the product allows the production facilities to be specialized. Economy, through the application of mass production techniques, is well known. The development of conveyors, jigs, fixtures, the familiarity of the workers with the equipment, work methods, and ship design are all greatly enhanced as the ship design is standardized.

Facilities are organized in one of three ways according to the layout of equipment and the movement of material:

1) Fixed-position layout where the product stays in one position and material is brought to it;

2) Process layout where material is routed to different areas where specialized processes (different for each area) are carried out; and

3) Product flow layout where work-in-progress is moved by conveyor or similar means from one work station to the next.

Shipbuilding uses all three. The last several decades has shown an overall movement from the first and second to the second and third in the attempt to apply mass production technology, i.e., from ship construction to ship production. IHI has made a concerted effort to carry the evolution as far as possible.

Recently American and European manufacturers in other industries have introduced the concept of "Group Technology". IHI uses the term to include family manufacturing, process-lanes, worker groups, and product-work-breakdown. A basic component of group technology is the set of requirements imposed on the parts classification and coding system.

This coding leads directly to computerization. In fact, successful computerization of a shipbuilding data base is directly correlated with successes in standardization. Computer-aided design, computer-aided manufacturing (CAD/CAM) and computer-aided process planning (CAPP) all require standardized data in computerized files.

## IHI'S STANDARDIZATION EFFORTS

Overall, IHI views its standardization efforts as:

1) a long range planning effort
2) a means of resolving recurring problems
3) documentation of things learned
4) cost reduction

Standards are a tool for communication. Design standards developed with the aid of production personnel formalize design practices best suited for both design and production. These standards in turn provide "instant experience" to new personnel. Material standards are the shorthand notes between Design and Purchasing Departments reducing the volume of descriptive data as well as reducing the variety of materials and supplies maintained in inventory.

In the same way, tolerance standards provide a clean and definite set of agreements between the design, production, and quality assurance groups. Everyone knows what is required as well as having addressed and settled the questions of how much quality can be achieved for what cost.

Process standards cover not only basic marking, cutting, and welding processes but also assembly methods up to and including assembly specification plans which detail the methods to be followed during fabrication, assembly and erection. The most effective methods (and alternatives) are documented forming the basis for all future plans.

Having covered the what and the how, cost standards document the how much and how long. All of IHI's long-range and detailed schedules depend upon accurate feedback and documentation of the manhour costs from design through delivery. Consistency in product design, consistency in planning methodology, and consistency in production methods lead to greater consistency and lower costs in returned manhours.

The task for continually reviewing, updating old standards, deleting obsolete ones, and creating new standards is recognized as vital and is a basic assignment for all members of the organization.

## APPLICATION OF IHI TECHNOLOGY

At the start of the TTP program, a parallel effort was being made by Livingston to reorganize, codify and streamline all phases of documentation. Figure 1-1 illustrates the pyramid structure of that effort. Standards then as now formed the base. This arrangement was overwhelmingly and repeatedly confirmed by the practices and methods utilized by IHI.

INTEGRATED HIERARCHY OF DOCUMENTATION

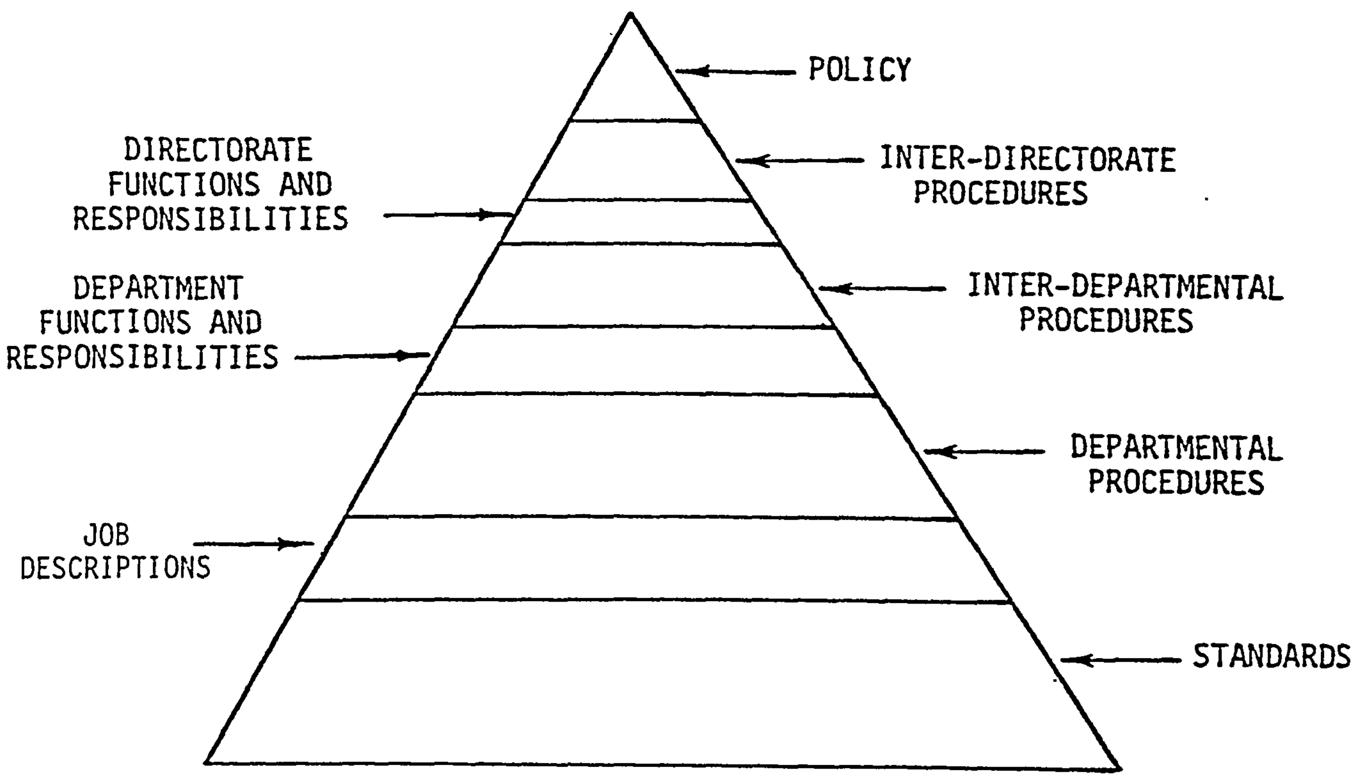



FIGURE 1-1

# DESIGN STANDARDS

## DEVELOPMENT OF NATIONAL AND SHIPYARD STANDARDS

That a significant difference exists between the role of the governments of Japan and the U. S. in promoting national standards is not new to U. S. shipbuilders. The Japanese Industrial Standardization Law gives that government the authority to select a designated commodity or designated processing technique for a product. This is done when the quality of the commodity or product must be guaranteed due to its widespread use of manufacture.

IHI developed its own set of standards to supplement the JIS: in the early 1960's, a major effort to establish in-house standards was initiated. Special task groups were organized in several departments of each yard--Design, Fabrication, Assembly, Erection and Outfitting, etc.--each with the requirement to produce several standards per month. This was continued over a two-year period at which time about 80 percent of IHI's current standards were identified and draft standards prepared.

The development of yard plans from the key plans depends heavily on standardization. Numerous plans and schedules must be developed. A detailed schedule of supplying drawings to the yard is prepared as the "Design Procedure and Drawing Supply Schedule" for a particular ship type and is referred to as a "Management Standard".

Standards on coding, design practices, production practices, drafting room procedures, material specifications and so forth are reduced in size and bound in book form for ready reference by designers and drafters. These ready reference manuals put the shipyards accumulated experience directly in the hands of those who need them. They also help to ensure uniformity of application within departments and compatibility among departments.

## ORGANIZATION AND USE OF IHI STANDARDS

For the purposes of the TTP, IHI design standards were classified into three categories based on the type of information given:

1) General definition and material coding standards

2) Detailed design standards

3) Production standards

# MATERIAL STANDARDS

## INTRODUCTION

One of the most striking aspects of shipbuilding is the large quantity and wide range of materials required. A vast amount of information is required to be passed among the departments and to vendors. IHI has developed standards both as a means of communication and as basis for a computerized data base.

This section describes how material standards fit into the IHI system.

## MATERIAL STANDARDS AND THE DESIGN PROCESS

For the designer, the material standards perform two functions. First, they tell him what is stocked (or available at short notice) and second, the interfacing requirements for components and equipment, e.g., machinery and foundations, valves and piping, etc. For raw materials, there are corresponding design application standards specifying the range and increment of sizes to be used.

Designers specify material in one of three ways:

1) By code referencing a material standard (Standard Drawing) Material requisition classification T.

2) By purchase order specification. Normally, off-the-shelf items in accordance with national standards or vendor-supplied information. Material requisition classification P.

3) By developing Fabrication Drawings for material to be manufactured by subcontractors. Material requisition classification D.

It is by intent that the number of materials specified by standards (T) be much larger than the number specified by purchase order (Type P) or by Fabrication Drawing (Type D).

As discussed in the next section, reducing the number of different sizes for either raw materials or components leads to reduced costs for the material control system. This has an adverse effect on the designer, however, as he no longer has a wide a range of sizes from which to choose. Selecting the next size larger for an item to meet a requirement means over-design or over-specification in many cases. IHI design engineers quite readily accept this negative impact on design as part of their responsibility to reduce total shipbuilding costs.

## MATERIAL STANDARDS AND THE MATERIAL CONTROL SYSTEM

The typical IHI material control system is composed of several subsystems:

- -Data entry subsystem
- -Remainder appropriation subsystem (use up leftover materials prior to new purchases)
- -Leveling and balancing subsystem
- -Purchasing subsystem
- -Delivery control subsystem
- -Material receipt and inventory subsystem
- -Material issue subsystem (including palletizing)

Along with the material codes and material requisition codes, IHI also classifies material for inventory control purposes. The classifications are:

1) Stocked Materials (S-Material)
   General materials used on various kinds of vessels such as bolts, nuts, joints, packings, small chain, etc. This material is always on hand in a warehouse with set stocking levels periodically adjusted item by item as historical demand indicates.

2) Allocated Material (A-Material)
   Materials used for a specific vessel such as special valves, special pipes, or equipment. The type and quantity is specified item by item design and purchased in the quantity specified.

3) Allocated Stock Material (AS-Material)
   Materials used for a specific vessel but needed in large quantities such as pipe, flanges, elbows, etc. The material is ordered in leveled lots with total quantity determined as the design is finalized.

There is a definite relationship between the material requisition codes (T, P, and D) and the material control classes (S, AS, and A). Materials specified by standards (T) fall into all three of the control classes while those specified by the other two methods (P and D) are designated as Allocated Stock (AS) materials.

IHI has made consistent and concerted efforts to reduce the amount of material in inventory whether it be in the warehouse, steel stock yard or in-process.

Many major U.S. yards have realized reductions in inventory carrying costs (as well as the acreage) by standardizing the numbers of different sizes and thicknesses of steel plates. IHI has carried this process to other materials which in itself was a major driving force in the establishment of material standards.

LIVINGSTON APPLICATION

As a result of the study, Livingston developed its own version of a standard for sizes of steel plates and has started to revise its material stock catalog.

# TOLERANCE STANDARDS

## INTRODUCTION

In order to understand the importance and the development of tolerance standards at IHI, the Accuracy Control concept must first be explained.

The objectives of Accuracy Control are:

1) To maintain the highest accuracy possible at each stage of production of every fabricated piece, part, sub-assembly, assembly and erected unit.

2) To minimize the work at the erection stage.

3) To consistently improve the production stage to yield the highest accuracy in all products.

The main goal of Accuracy Control is to perfect each production method, technique and process to such a degree that each worker activity has definitive standards to be achieved, a prescribed method of measurement for finished material, and a continuous flow of information between activities resulting in the constant improvement of producti quality and production efficiency.

## TYPES OF TOLERANCE STANDARDS AT IHI

Tolerance standards at IHI have evolved from actual production practices over many years and many a series-run of ships. For many ship types, standard tolerances are firmly established and require little, if any, modification. In these cases, Accuracy Control Engineers simply review ship specifications for any requirements that would cause a change to those already in practice. In the case of a new ship type, standard tolerances are reviewed and changes effected where necessary to comply with specification requirements or with differing technical requirements for that ship. Generally, no major revision of tolerance standards is required even on new ship types.

## DEVELOPMENT OF TOLERANCE STANDARDS

IHI uses Accuracy Control check sheets to develop a history of recorded data on checks of fabricated, assembled and erected pieces. With a log containing over fifteen years collection of data, IHI was able to develop standard and tolerance tables for each of these processes on all units. The values of these tolerances are generally stricter than those established by the ship's owners and the Japanese classification societies. The JSQS (Japanese Shipbuilding Quality Standards) is the main source for Japanese shipbuilding standards.

## EXAMPLES OF TOLERANCE STANDARDS

Examples of tolerance standards for the two types of control, regular and special control, are provided as Figures 1-2 and 1-3.

## FEEDBACK SYSTEM - STATISTICAL ANALYSIS

From analysis of the measurement data, appropriate action is taken by the Accuracy Control Engineer through feedback of information to the applicable department or group. This feedback is a vital loop in the overall Accuracy Control scheme and not only prevents errors from recurring, but provides the action necessary to the continuing improvement of product and production system. Examples of this feedback are: a change to the dimension of added material requires a modification to the working drawing, therefore, Engineering is so notified; an addition of Baselines in the output of the mold loft requires feedback to the loft; a change in the fabrication method. or the platform at assembly or welding procedure requires feedback to Production and to the Planning and Design Staff responsible for a given workshop.

| SHOP | ITEMS TO BE CHECKED | ALLOWABLE TOLERANCE | FREQUENCY OF MEASURING |
|---|---|---|---|
| Marking & Gas Cutting | | | |
| (Section) | *Line for gas cutting of angles (after cutting) | e = ± 1/32" | 5 pc/day |
| | *Length of angles (after cutting) | e = ± 1.5/64" | 5 pc/day |
| (Internal Member) | *Normality after gas cutting (right angle) | e = ± 2mm per 1500mm | 5 pc/day |
| | *Line for gas cutting | e = ± 1/32" | " |
| | *Length after gas cutting | e = ± 3/64" | " |
| | *Width after gas cutting | e = ± 3/64" | " |
| <u>Flame Planer</u> | *Length & Width after cutting | e = ± 1.5/64" | 5 pc/day |
| (Flat Shell Plate Flat Plate | *Straightness | e = ± 1/64" | 2 pc/week |
| | *Bevel Angle | e = ± 2.0 deg. | 5 pc/day |
| | *Normality (Right Angle) | e = ± 2mm per 1500mm | 2 pc/week |

FIGURE 1-2

TOLERANCE STANDARDS REGULAR CONTROL (EXAMPLES)

| SHOP | ITEM | TOLERANCE | FREQUENCY OF MEASURING | REMARKS |
|---|---|---|---|---|
| ERECTION<br>Bottom Shell | *Positioning (Length wise) Measure on the check points on berth | e = ± 1/8" | Starting unit only | |
| | *Positioning: (Height) Measure at the most forward frame (2 points) | e = ± 1/4" | All Units | By Gauge |
| | *Level: (Between left side and right side) Measure on the points at forward edge | e = ± 1/4" | All Units | Pay attention to twist |
| | *Positioning: (Between left side and right side) Measure at the forward butt | e = ± 1/8" | All Units | Plumb down to the base line on berth |
| | *Connecting part between units: Check the bevels at seams and butts | e = ± 1/8" | All Units | |
| | *Discrepancy of ship's center | e = ± 1/8" | All Units | Measuring by transit |

FIGURE 1-3

TOLERANCE STANDARDS SPECIAL CONTROL (EXAMPLES)

## LEVINGSTON APPLICATIONS

The adoption of unitized construction of vessels increases the importance of tolerance standards to insure proper erectability of assembled units. IHI engineers contributed to the development of tolerance standards for Levingston compatible with the unit system being implemented. Levingston engineers reviewed IHI's tolerance standards for ideas on types of standards, format of information, and specific tolerance allowances.

Levingston published standards for welding and for joint details, including tolerance limit values, prior to TTP. These standards specify edge preparation, fitting and welding techniques as allowed in the welding procedure qualification process. Since inception of TTP, Levingston has issued tolerance standards for hull construction in the areas of hull details (e.g., fitting accuracy), ship design (overall hull dimensional deviations), in piping (e.g., butt weld fitting material requirements), and in flat panel assembly (e.g., structural alignment). Examples of Levingston's tolerance standards are given as Figures 1-4 and 1-5. Tolerances are an indication of the lowest acceptable level of performance and not to be interpreted as an allowable standard for everyday work.

## CONCLUSION

Tolerance standards for a given shipyard must reflect the conditions, equipment and methods of operation at that particular facility. The standards are invaluable to maintain a satisfactory program of accurate workmanship. The data collection system used to develop these standards, the flow of information to appropriate departments, and the standards devised by classification groups or used at other locations are transferable as guidelines for a facility to use in initiating its own program.

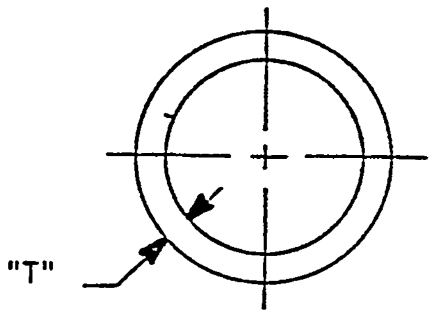
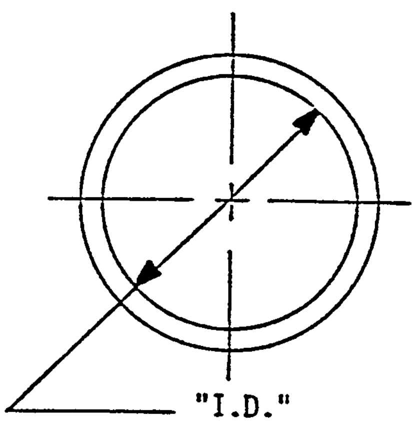
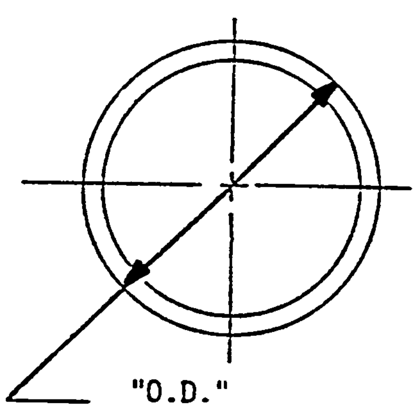
| OBJECT | | MATERIAL | | |
|---|---|---|---|---|
| TYPE | SUB TYPE | ITEM | TOLERANCE LIMIT | REMARKS |
| PIPE AND BUTT WELD FITTINGS | WALL THICKNESS |   | T = THICKNESS<br><br>THE WALL THICKNESS SHALL NOT AT ANY POINT BE LESS THAN 87 1/2% OF THE NOMINAL THICKNESS. | PER ANSI B16.9 |
| | INSIDE AND OUTSIDE DIAMETERS |   | I. D. = INSIDE DIA.<br><br>A. UP TO 2 1/2" -- ± 1/32"<br><br>B. 3" TO 8" - ± 1/16"<br><br>C. 10" TO 18" - ± 1/8"<br><br>D. 20" TO 48" - ± 3/16" | PER ANSI B16.9 |
| | |   | O.D. = OUTSIDE DIA.<br><br>A. UP TO 2 1/2" +1/16" - 1/32"<br><br>B. 3" TO 4" +1/16" -1/16"<br><br>C. 5" TC 8" +3/32" -1/16"<br><br>D. 10" TO 18" +5/32 -1/8"<br><br>E. 20" TO 48" +1/4" -3/16" | PER ANSI B16.9 |

FIGURE 1-4 LEVINGSTON TOLERANCE STANDARDS - EXAMPLE

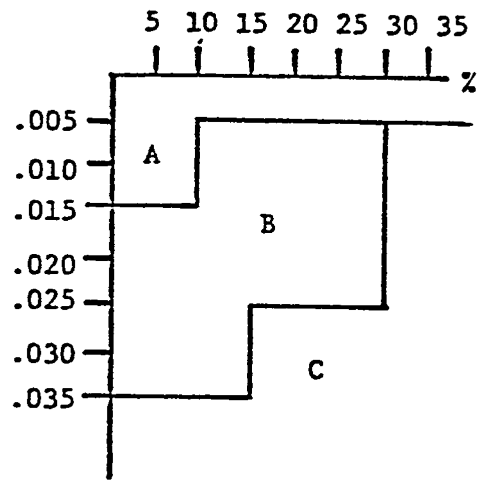
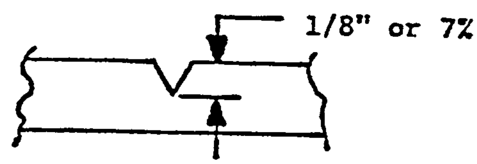
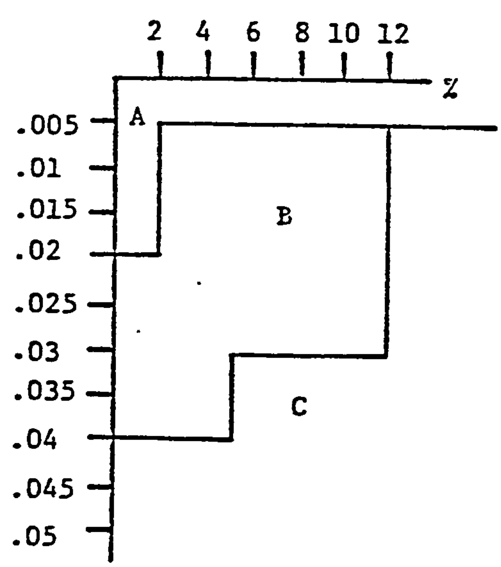
<table>
<tr><th colspan="2"></th><th colspan="2">MATERIAL</th></tr>
<tr><th>TYPE</th><th>SUB TYPE</th><th>ITEM</th><th>REMARKS</th></tr>
<tr><td rowspan="2">SURFACE FLAW</td><td>PIT</td><td>SURFACE AREA RATIO<br><br>DEPTH<br>(Decimal of Inches)</td><td>1) GRADE "A" - SLIGHT NO REPAIR NECESSARY.<br>GRADE "B" - MEDIUM DISORDER, REPAIR IF NECESSARY.<br>GRADE "C"- SERIOUS DISORDER NEEDS REPAIR.<br>2) REPAIR METHOD - GRIND OR WELD & GRIND.<br>MILL STANDARD = 1/8" or 7% OF PLATE THICKNESS.<br></td></tr>
<tr><td>FLAKING</td><td>SURFACE AREA RATIO<br><br>DEPTH<br>(Decimal of Inches)</td><td>1) GRADE "A" - SLIGHT NO REPAIR NECESSARY.<br>GRADE "B" - MEDIUM DISORDER REPAIR IF NECESSARY.<br>GRADE "C" - SERIOUS DISORDER. NEEDS REPAIR.<br>2) REPAIR METHOD - SAME AS PIT REPAIR</td></tr>
</table>

FIGURE 1-5 LEVINGSTON TOLERANCE STANDARDS - EXAMPLE

The IHI system was discovered to be very comprehensive, containing rigid standards by comparison to Levingston’s past guidelines for tolerances

The feedback system is an essential ingredient for developing, maintaining and revising tolerance standards. The system relies on a substantial amount of data collection, but amply compensates for itself by providing information vital to sustaining a reliable accuracy control program. This becomes especially visible at the assembly and erection stages, where ease of fit-up is directly related to the accuracy of work in the preceding stages. Improvements in this area easily justify a comprehensive program of well-established tolerance standards for any shipyard.

## PROCESS STANDARDS

### INTRODUCTION

A process standard is an established method prescribing a uniform sequence for performing an operation or set of operations.

This definition is presented in order to distinguish a process standard from a cost standard as they are described in this report. The main distinction can be expressed by stating that a measurement of performance of a "process standard"results in a "cost standard".

A process is an operation or sequence of operations performed on a component which changes the characteristics of the component.

In this context, then, a process may be broad (e.g., cutting, assembly) or specific (N/C cutting, flat panel assembly).

IHI maintains a wealth of process standards in the forms of manuals, operating guidelines, written procedures, instructions, etc., which are used throughout the shipbuilding process. They also maintain numerous records, lists and logbooks which are used to develop these standards.

### SIGNIFICANT DIFFERENCES (IHS VS. LEVINGSTON) & SUGGESTED IMPROVEMENTS

Within the processes, the greatest points of differences were found to be in the sub-assembly and assembly areas. Specific differences and recommended improvements for standardization of the processes included the following:

1) Maximize assembly of small pieces at the sub-assembly stage, thereby decreasing the amount of this minute work required at assembly stages.

2) Classification of assembly work into the categories previously listed with the following objectives:

- Maximum utilization of facilities to obtain the highest productivity.

- Achievement of the most performance by means of having workers permanently stationed at fixed work sites.

3) Utilization of welding in the flat position, in order to obtain good performance and high productivity.

In the area of outfitting, specific recommendations made by IHI to improve on the standardization concept concerned greater utilization of:

1) Pre-Outfitting: Module Stage

2) Pre-Outfitting: On-Unit Stage

3) Pipe Fabrication: In the Shop

This section on Process Standards is specifically aimed at the aspect regarding standard work flow in each area, particularly the detail procedures for each area. This procedure requires analysis of the facilities and the work breakdown assignments, examinations of methods for their description, and improvement and identification of the skills and equipment needed. The process standards will then be used to develop time standards, cost standards and manpower requirements to analyze productivity and to provide data for planning and scheduling purposes. The objective of standardizing processes is to organize procedures in a uniform and repetitious manner for use in formulating accurate schedules in the easiest fashionable manner.

PRELIMINARY PLANNING

Process standards will deal with the procedures specifying the methods to be employed. These consist of rough procedures drawn up in the early stages as planning efforts in the assignment of work within gates, and the detail procedures designating the method of constructing each assembly unit.

These process standards are used to develop cost standards, which are vital elements toward establishment of accurate schedules.

DETAIL PROCEDURES

The purpose of specifying detail procedures is to establish efficient, uniform, sequential patterns of work plans for field personnel to follow. These procedures aid in job preparation by stipulating in advance the necessary materials, equipment, jigs and components that will be needed. These guidelines assist foremen and improve the working environment in the following ways:

1) Establishes a pre-determined standard method of operation.
2) Prescribes the most effective sequence of activities.
3) Specifies arrangement and uses of necessary jigs and fixtures.
4) Issues warning notes to exercise care in the work being done in order to avoid a future problem.
5) Provides consistency between foremen, between shifts, between departments, etc.
6) Designates details of work within a specific area and its relationship to other supporting work.
7) Gives a broad overview of the total scope of work for better understanding of each individual segment.

ASSEMBLY PROCEDURES AND GUIDELINES

Formal procedures of specified assembly plans have been written by Industrial Engineering and issued to the Production Departments. These procedures have been issued for each hull under construction since the first bulker (including duplication for like hulls). The procedures specify the assembly methods for each typical unit in the hull, complete with sketches, detailed instructions, sequence of steps, crucial dimensions, arrangements of the unit with jigs, and other necessary information. An example of a typical Assembly Procedure and Guideline issued for the construction-of the bulker is given as Figure 1-6.

This procedure has been welcomed by the Production Department as an effective aid to promote uniform methods and procedures, to visualize the assembly process, to help avoid problems in assembly and accuracy control, and to plan their work.

## WORK MANUALS

It is Levingston’s plan to issue work manuals for each gate or set of related gates. These work manuals are visualized to contain such information as working procedures, gate layout, material flow, data collection, forms, statistical reports and charts generated, quality standards, safety precautions, manpower assignments, and the like.

## CRAFT HANDBOOKS

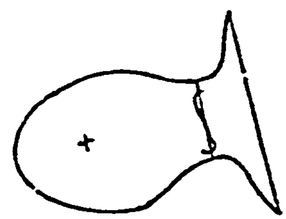
Another desirable form of standards document is a handbook for each craft. IHI issues handbooks to each worker specifying guidelines to follow in the performance of his work. These handbooks contain both general and specific guidelines concerning such subjects as work tools, job procedures, safety precautions, quality standards, etc.

The writing and issuing of these types of handbooks are not foreseen in the near future for Levingston but are prospective goals. Information for welders use is currently being generated that would be included in this type of handbook.

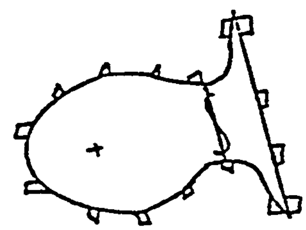
## TYPICAL CONSTRUCTION ASSEMBLY SKETCH

### LSCo ASSEMBLY PROCEDURES AND GUIDELINES
FOR UNIT 241

1. FIT AND WELD FR. 10 PLATE
   (30TH SIDES) ON FIAT SLAB.

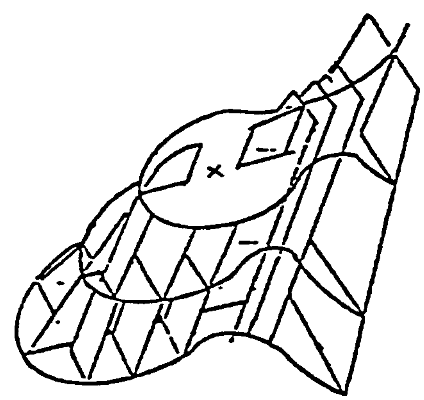


2. SEI NECESSARY SUPPORTS AT
   LEAST 10" HIGH. SET FR. 10
   PIATE 0IL SUPPORTS.



5. SET AND FIT STRUCTURALS, FLAT
   AND FRAILING ON FR. 10 PIATE.

   HELD INTERNALS.



4. PUT CASTING ON.

5. PUT SHELL PLATE ON IN SEQUENCE OF
   A-B-C-D-E-F AND FINISH WELDING,

   PUT SHELL PLATES G-H-I-J ON AND
   FINISH WELDING.

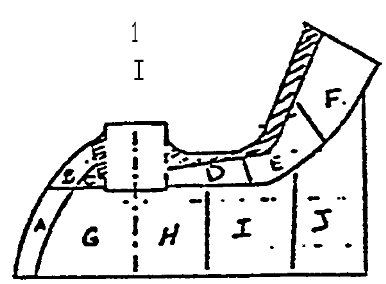



FIGURE 1-6

# COST STANDARDS

## INTRODUCTION

One of the most impressive aspects of the IHI production system is the remarkable adherence to schedule. The development of precise scheduling techniques is the result of carefully planned, thoroughly documented information systems which are devised to develop standard data. The process standards discussed in the foregoing section specify the proper methods to be followed which result in procedural standardization. The subsequent step is the measurement of performance resulting from application of these process standards, amounting to standardized units of time per product, or numbers of product per time element, which are the basis for cost standards.

In conjunction with establishment of standardized work procedures, or process standards, a measurement system of the rate of production results in performance standards. These standards form the basis of cost standards, which are defined in this report as:

A <u>cost standard</u> is a measured rate of production for a given process to be used in planning, scheduling and estimating activities and to calculating the cost of the process.

Examples of cost standards in the shipbuilding process include: man-hours per ton, inches per minute (cutting), feet per hour (welding), etc.

## DOCUMENTS

There are a number of status reports recommended by IHI for use in the development and application of cost standards:

1) Manhour Collection Sheets

   a) Daily record of manhours spent on each unit, by worker name. (See Figure 1-7)

GATE ______ FOREMAN ____________________ SHIFT ______________

| WORKER / UNIT | I.K. | B.T. | E.F. | T.R. | S.S. | H.K. | C.L. | R.M. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 8 | 8 | 8 | 8 | 8 | 4 | 4 | 4 | | | | | $52^H$ |
| 111 | | | | | | 4 | 4 | 4 | | | | | $12^H$ |
| | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | |

FOREMAN ____________________ SHIFT ______________

| WORKER / UNIT | I.K. | B.T. | E.F. | T.R. | S.S. | H.K. | C.L. | R.M. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 8 | 8 | 8 | 8 | 8 | | | | | | | | $40^H$ |
| 111 | | | | | | 8 | 8 | 8 | | | | | $24^H$ |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
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DAILY MANPOWER RECORD (SAMPLE)

FIGURE 1-7

b) Monthly record, composed of summation of data on daily records. (See Figure 1-8)

2) Efficiency Records on productivity, e.g., meters/hour ratio on welding. (See Figure 1-9)

3) Blackboards -- Displays posted in designated areas specifying schedules, productivity, quality or work, etc. (See Figure 1-10)

## DEVELOPMENT OF COST STANDARDS

The purpose for developing process standards and cost standards from the IHI viewpoint is for use in the following applications:

1) Base data for estimating manhour requirements

2) Base data for estimating periods of completion for jobs

3) Base data used toward determining needed improvements in equipment and facilities

4) Base data used in status reporting and applied toward improving productivity.

5) Educational material and training aids for field personnel

The data used to calculate cost standards are derived from the previously developed process standards. The approach recommended by IHI for the deter: mination of process standards first involves classification of the elements to study. The basic elements regarding hull construction are listed in Table T1-1.

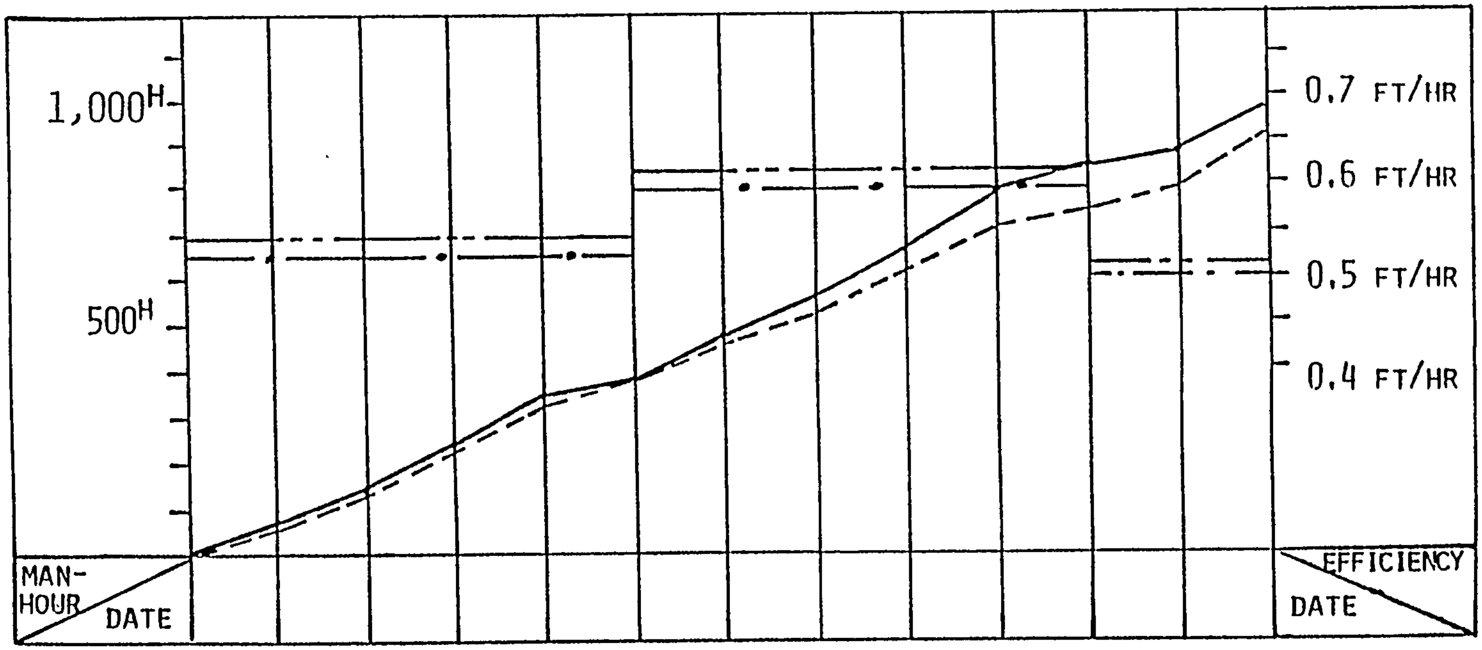
By studying and analyzing these basic elements of the shipbuilding cycle, a shipyard can determine the control parameters it may best utilize for each element. This can be determined by the data collected at the facility, the measurement technique it can best employ with the resources it has available, and the accuracy and applicability of the data measured. Table T1-2 specifies the measurement parameters used at IHI for each working stage. Also included

CRAFT: FITTERS

| UNIT | W.L. (FT) | ISSUED MAN-HOURS | DAILY MANHOURS CHARGED | | | | | | | | | | | | | | | | | | | | TOTAL MAN-HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6/9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 | 19 | 20 | 23 | 24 | 25 | 26 | 27 | 30 | 7/1 | 2 | 3 | 4 | |
| 101 | 470 | 115 | | | | 16 | 16 | 32 | 32 | 32 | 16 | 16 | | | | | | | | | | | $128^H$ |
| 111 | 520 | 125 | | | | | | | | 16 | 16 | 32 | 32 | 32 | 16 | | | | | | | | $144^H$ |
| 121 | 485 | 120 | | | | | | | | | | | | | 16 | 32 | 32 | 32 | 24 | | | | $136^H$ |
| 131 | 490 | 120 | | | | | | | | | | | | | | | | | 8 | 32 | 32 | 32 | $104^H$ |
| | | | | | | | | | | | | | | | | | | | | | | | |

| UNIT | W.L. (FT) | ISSUED MAN-HOURS | DAILY MANHOURS CHARGED | | | | | | | | | | | | | | | | | | | | TOTAL MAN-HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 7/7 | 8 | 9 | 10 | 11 | 14 | 15 | 16 | 17 | 18 | 21 | 22 | 23 | 24 | 25 | 28 | 29 | 30 | 31 | 8/1 | |
| 131 | 490 | $120^H$ | 16 | | | | | | | | | | | | | | | | | | | | $120^H$ |
| 141 | 465 | $115^H$ | 16 | 32 | 32 | 16 | 16 | 16 | | | | | | | | | | | | | | | $128^H$ |
| 151 | 515 | $125^H$ | | | | 16 | 16 | 16 | 32 | 32 | 16 | | | | | | | | | | | | $128^H$ |
| 161 | 510 | $120^H$ | | | | | | | | | 16 | 32 | 32 | 32 | 16 | 16 | | | | | | | $144^H$ |
| 171 | 495 | $120^H$ | | | | | | | | | | | | | 16 | 16 | 32 | 16 | 16 | | | | $128^H$ |

FIGURE 1-8 MONTHLY REOCRD OF MANHOURS (SAMPLE)




LEGEND

AVERAGE (ACTUAL)

AVERAGE (GOAL)

CUMULATIVE (ACTUAL)

CUMULATIVE (GOAL)

EFFICIENCY CHART

FIGURE 1-9

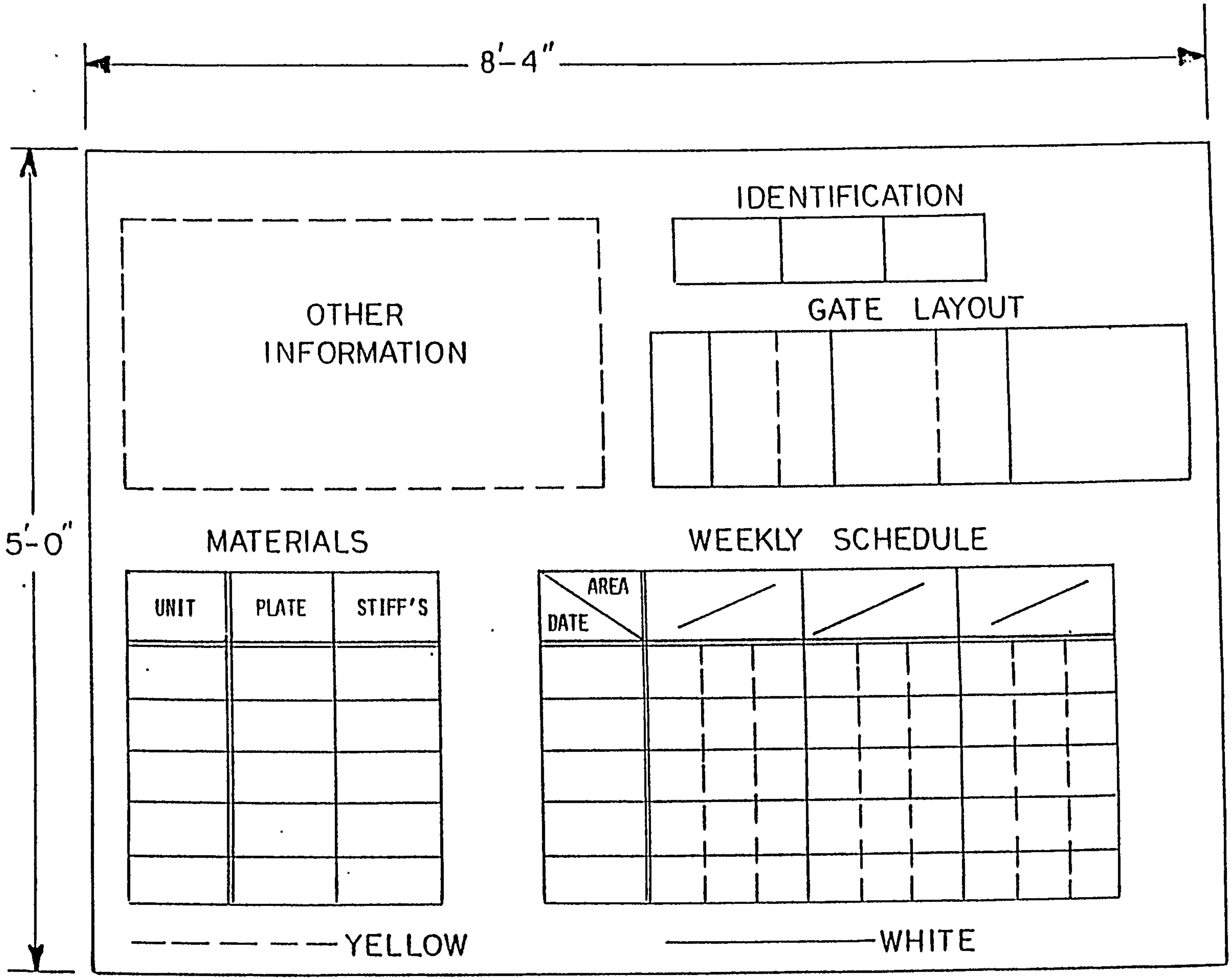



FIGURE 1-10 DESCRIPTION OF BLACKBOARD (SAMPLE)

TABLE T1-1

PROCESS STANDARD ELEMENTS

| ELEMENTS | EXPLANATION/EXAMPLES | INFLUENCING FACTORS |
|---|---|---|
| A. Material Handling | Raw materials, pieces, sub-assemblies, assembled units, etc. | 1. Method of transportation<br>2. Equipment options<br>3. Frequency<br>4. Distance |
| B. Marking | N/C, Flame Planer, Manual at Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Marking length |
| C. Cutting | N/C, Flame Planer, Manual at Fabrication, Assembly, Erection | 1. Method<br>2. Instrument<br>3. Environment<br>4. Plate thickness<br>5. Cutting length<br>6. Type of bevel |
| D. Bending | Plate, Structural, Bracket, Face Plate, etc. | 1. Method<br>2. Thickness<br>3. Amount of Curvature |
| E. Fitting | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Fitting length<br>4. Gap |
| F. Welding | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Leg length<br>4. Material quality<br>5. Welding length |
| G. Finishing | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. No. of temp. pieces<br>4. Material quality |
| H. Painting | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Area Painted<br>4. Type of Coating |

TABLE T1-2

CONTROL PARAMETERS

| SHOP | STAGE | WORKING | PARAMETER (IHI) | EFFICIENCY (IHI) | RECOMMENDED PARAMETER (LSCO) |
|---|---|---|---|---|---|
| FABRICATION | MARKING & CUTTING | EPM | NUMBER of plate | 0.5 H/PL | NUMBER |
| | | FLAME PLANER | " | 1.12 H/PL | |
| | | CURVATURE CUTTING | " | 2.85 H/PL | |
| | | N/C CUTTING | " | 4.66 H/PL | |
| | | SKELETON MEMBER CUTTING | " | 4.68 H/PL | |
| | | ANGLE CUTTING | " | 0.69 H/PC | |
| | | DECK HOUSE CUTTING | " | 6.22 H/PL | |
| | | SUB TOTAL | TONNAGE | 1.43 H/T | TONNAGE |
| | BENDING | ANGLE BENDING | NUMBER of piece | 1.5 H/P | NUMBER |
| | | PLATE BENDING | " of plate | 7.7 H/PL | |
| | | SMALL PIECE BENDING | " of piece | | |
| | SUB. ASSEM. | FITTING | W.L. | 6.2 M/H | NUMBER |
| | | WELDING | W.L. | 5.4 M/H | |
| | | MATERIAL SORTING | TONNAGE | 0.5 H/T | TONNAGE |
| | | SUB TOTAL | TONNAGE | 8.95 H/T | |
| | OTHERS | MATERIAL HANDLING | TONNAGE | 0.23 H/T | TONNAGE |
| | | SHOT BLASTING | NUMBER of plate | 0.48 T/PL | NUMBER |
| | | CRANE | | | |
| | | T.TYPE LONGL. | NUMBER of piece | 12.5 H/P | NUMBER |
| ASSEMBLY | EACH SHOP | PLATE JOINING | A.W.L. | 1.84 M/H | A.W.L. |
| | | FITTING | W.L. | 7.68 M/H | W.L. |
| | | WELDING | W.L. | 3.46 M/H | W.L. |
| | | FINISHING | W.L. | 20.09 M/H | W.L. |
| | | MATERIAL HANDLING | TONNAGE | 0.65 H/T | TONNAGE |
| ERECTION | PRE.ERE. SKIN. SKELETON | FITTING | W.L. | 2.77 M/H | W.L. |
| | | WELDING | W.L. | 0.91 M/H | W.L. |
| | | FINISHING | W.L. | 11.50 M/H | W.L. |
| OTHER JOB | | SCAFFOLDING | TONNAGE | | TONNAGE |
| | | CRANE | " | | |
| | | TRANSPORTATION | " | | |
| | | | | | |
| | | | | | |
| | | | | | |

in this table are the efficiency factors achieved at IHI and the parameters recommended for application at Levinston. These parameters are used to measure the performance factors that become the established cost standards.

CONTROL PARAMETERS

Table T1-2 reveals that IHI uses the following units of measurement as control parameters in their establishment standards:

Number of plates

Number of pieces

Tonnage

Welding Length (W.L.)

Automatic Welding Length (A.W.L.)

IHI seeks to use a parameter that relates to the time involved for processing of material as the primary consideration. Their objective is to use the simplest method of measurement without sacrificing accuracy or reliability of the data that is generated.

MEASUREMENT OF WELDING LENGTH

As mentioned earlier, there are two distinct methods utilized at IHI for the measurement of welding length. This length is determined by using either:

1) Conversion from unit weight

2) Measurement on drawings

The former method is a rough estimate based on weight and location of the piece. It is not sufficiently accurate to use in detail planning and scheduling of work within gates as performed by the Planning Department. The calculations in this method are made by the Engineering Department.

The latter method is more exact and useful in detail planning and control. It requires measurements from key plan drawings and requires a considerably greater investment in time. IHI estimates Levingston would expend approximately 100 to 120 hours to take the measurements on a vessel the size of the F-32, a 36,000 D.W.T. bulk carrier.

## ESTIMATING MANHOURS

### Hull Estimate

IHI uses combinations of techniques to estimate manhour requirements for an activity. The most common technique is use of historical data together with staff personnel experience to estimate manhours. On occasion, time study is used where historical data is not available, such as for a new process.

1. Coefficients - Rough Estimates

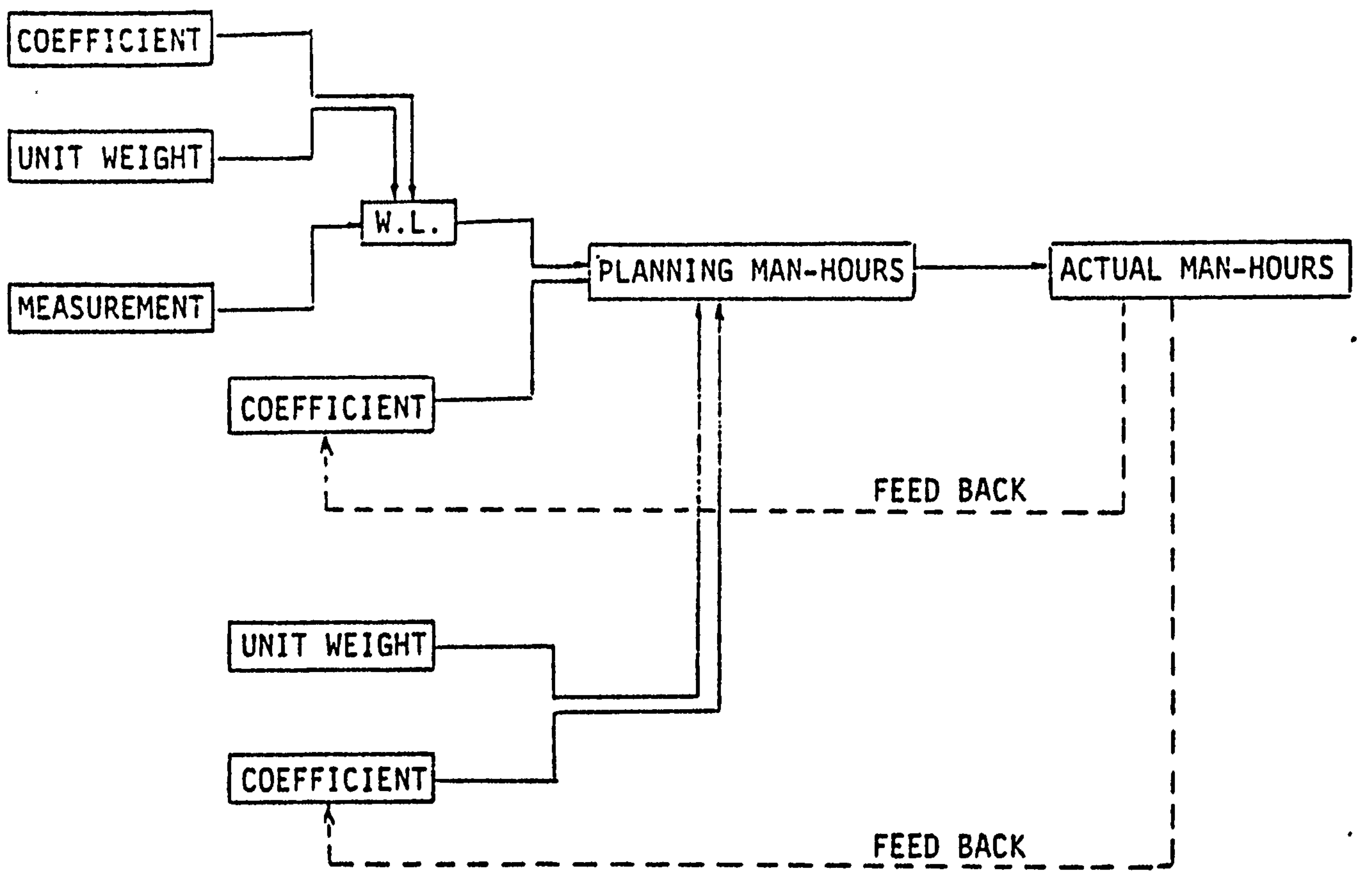
For planning purposes, IHI uses records of actual manhours to calculate difficulty factors, or "coefficients", that are used to estimate future manhour requirements. These coefficients are used to convert unit weights to welding lengths, which is extended by formula to determine manhours. The correlation between actual manhours, coefficient factors, unit weights, welding lengths and planning manhours is illustrated schematically in Figure 1-11.

IHI staff personnel recognize the variability of manhour requirements, depending on the existence or absence of various conditions. These are categorized into two groups:

a) Those dependent on the structure itself, such as:

- Classification of steel: mild steel vs. high strength steel

ESTIMATION OF MAN-HOURS AT ASSEMBLY STAGE




ESTIMATION OF MANHOURS AT ASSEMBLY STAGE
FIGURE 1-11

- Type of floor: watertight vs. non-watertight bulkhead
- Shape of structure,e, e.g., flat, curved, cubic (three-dimensional odd-shaped units), width, length, etc.
- Number of small pieces involved
- Difficulty to achieve accuracy.

b) Factors independent of the structure itself, such as:

Weather
Conditions for material preparation
Accuracy achieved in fabrication, fitting, assembly, etc.
Manpower leveling
Equipment availability
Condition of slab
Production procedures
Distribution of manpower

2. Coefficients - Detail Estimates

The estimating of manhours must also be performed in more detailed fashion. Where this is required, IHI engineers applied the same principles involved in the creation of coefficients on the charts of Figure 1-12 to develop a Table of Manhours and Efficiency for each assembly unit on the bulker. This data is presented in Table T1-3, a sample showing representative units within the double bottom area.

OUTFITTING

The on-module pre-outfitting assembly method practiced by IHI, with its standardized work procedures, lends itself readily to formulation of reliable cost standards. The manhours expended on a module assembly are captured and applied as standards and efficiency targets for installation of similar modules on subsequent ships. The data is continually updated and refined over periods of years, which results in increasingly accurate data for application as budgets and goals. The system of manhour goal calculations in the planning process is illustrated in Figure 1-13.

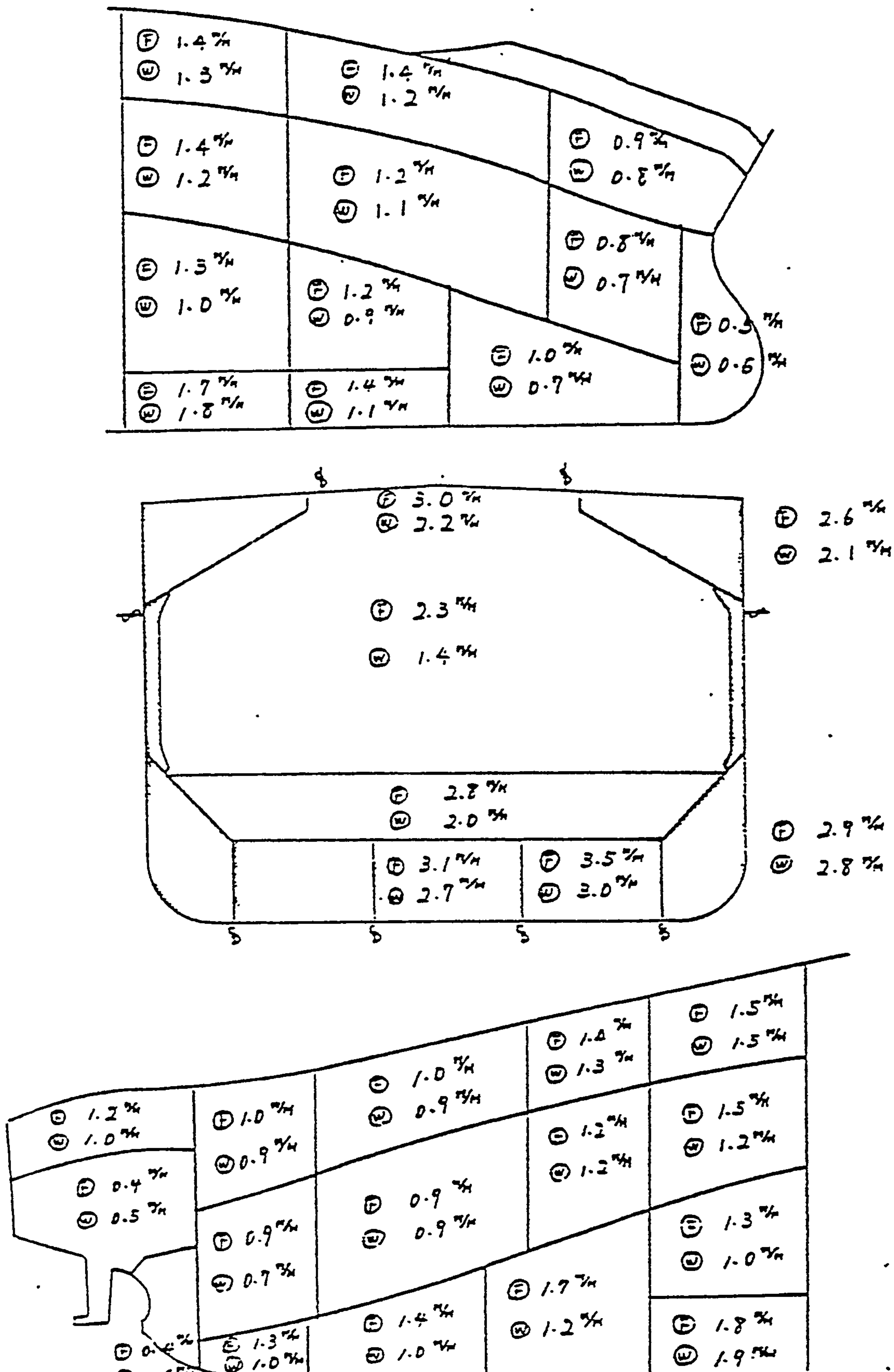
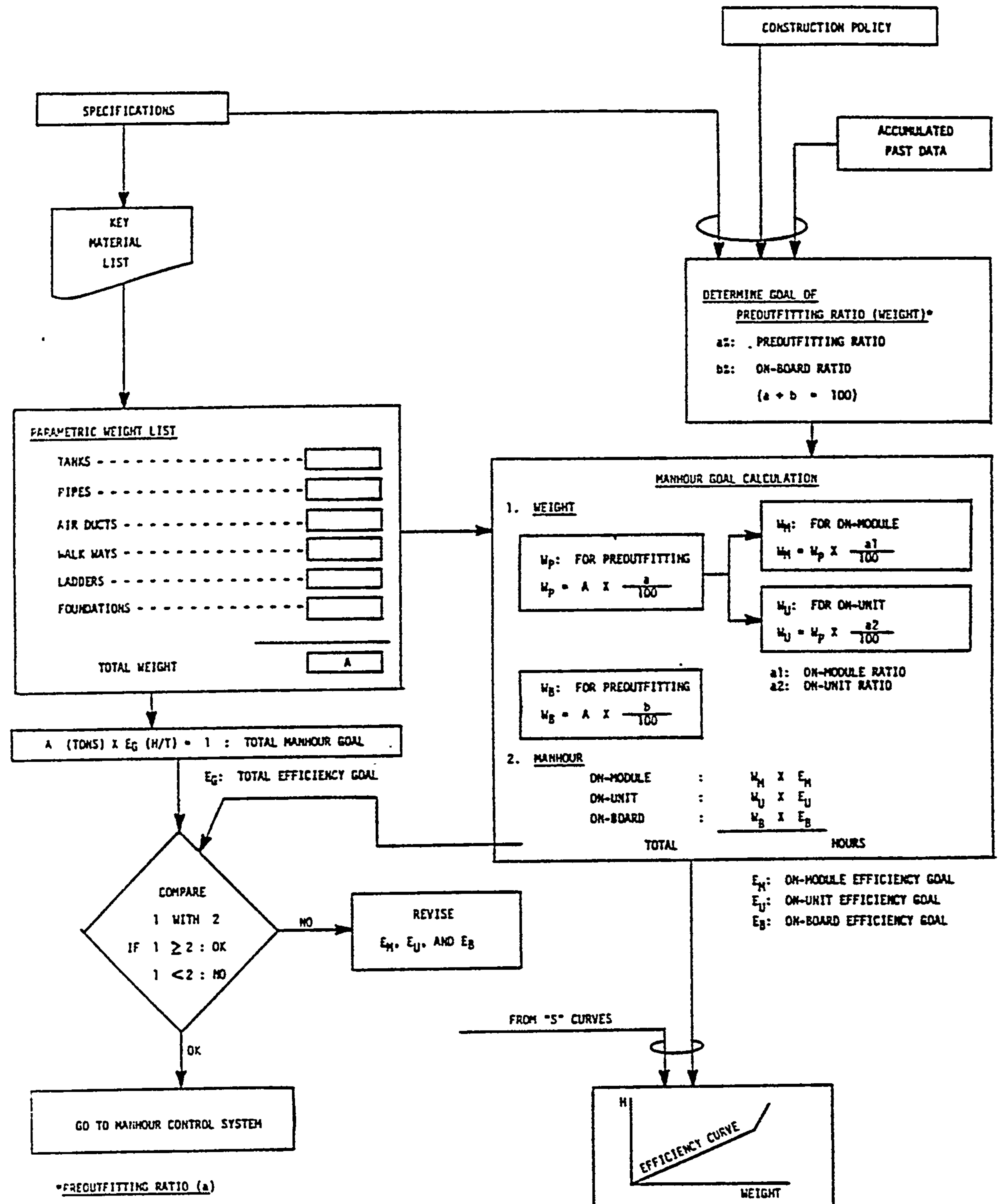



FIGURE 1-12 COEFFICIENT FOR EACH UNIT

## TABLE T1-3

## TABLE OF MANHOURS AND EFFICIENCY

| UNIT | WEIGHT | CONVERT RATIO | WELDING LENGTH | EFFICIENCY M/H | | MAN-HOURS | | EFFICIENCY H/T | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FITTING | WELDING | FITTING | WELDING | FITTING | WELDING | TOT. |
| W.T. | Ton | T 9.4 | 578 M | 3.8 M/H | 3.1 M/H | 155 H | 190 H | | | |
| 101 | 61.52 | B 6.6 | 406 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 984 | | | 320 | 360 | 5.2 H/T | 5.8 H/T | 11.0 |
| | | T 9.7 | 571 | 4.3 | 3.4 | 135 | 170 | | | |
| 111 | 58.91 | B 6.3 | 371 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 942 | | | 260 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | | T 9.4 | 578 | 3.8 | 3.1 | 155 | 190 | | | |
| 121 | 61.44 | B 6.6 | 406 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 984 | | | 320 | 360 | 5.2 | 5.8 | 11.0 |
| | | T 9.7 | 581 | 4.3 | 3.4 | 135 | 170 | | | |
| 131 | 59.95 | B 6.3 | 380 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 961 | | | 260 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | | T 9.4 | 583 | 3.8 | 3.1 | 155 | 190 | | | |
| 141 | 61.99 | B 6.6 | 409 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 992 | | | 320 | 360 | 5.2 | 5.8 | 11.0 |
| | | T 9.7 | 578 | 4.3 | 3.4 | 135 | 170 | | | |
| 151 | 59.58 | B 6.3 | 375 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 953 | | | 260 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | | T 9.4 | 581 | 3.8 | 3.1 | 155 | 190 | | | |
| 161 | 61.86 | B 6.6 | 408 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 989 | | | 320 | 360 | 5.2 | 5.8 | 11.0 |
| | | T 9.7 | 581 | 4.3 | 3.4 | 135 | 170 | | | |
| 171 | 59.95 | B 6.3 | 380 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 961 | | | 260 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | P | T 8.1 | 315 | 4.3 | 3.4 | 75 | 95 | | | |
| 102 | 38.74 | B 6.9 | 268 | 3.0 | 2.7 | 90 | 100 | | | |
| | S | 15.0 | 583 | | | 165 | 195 | 4.3 | 5.0 | 9.3 |
| | P | T 8.1 | 312 | 4.6 | 3.6 | 70 | 90 | | | |
| 112 | 38.74 | B 6.8 | 265 | 3.2 | 2.9 | 85 | 95 | | | |
| | S | 15.0 | 577 | | | 155 | 185 | 4.0 | 4.8 | 8.8 |
| W.T. | P | T 8.1 | 315 | 4.3 | 3.4 | 75 | 95 | | | |
| 122 | 38.74 | B 6.9 | 268 | 3.0 | 2.7 | 90 | 100 | | | |
| | S | 15.0 | 583 | | | 165 | 195 | 4.3 | 5.0 | 9.3 |
| | | T 8.1 | 312 | 4.6 | 3.6 | 70 | 90 | | | |
| 132 | 38.74 | B 6.8 | 265 | 3.2 | 2.9 | 85 | 95 | | | |
| | | 15.0 | 577 | | | 155 | 185 | 4.0 | 4.8 | 8.8 |




*PREOUTFITTING RATIO (a)

$$a = \frac{\text{PARAMETRIC WEIGHT OF PREOUTFITTING MATERIAL}}{\text{TOTAL PARAMETRIC WEIGHT OF OUTFITTED MATERIAL}} \times 100$$

RECOMMENDED OUTFIT PLANNING BY PARAMETRIC WEIGHT

FIGURE 1-13

## DEVELOPING STANDARD TIMES

It is apparent that the key to development of reliable process standards and cost standards for outfitting functions are dependent upon standardized, uniform working procedures and accurate manhour reporting, as was mentioned in the case of steel construction. This is accomplished by maintaining charts and graphs of actual productivity, by providing feedback on the accuracy of the projected standards, and by taking corrective action when discrepancies appear.

Examples of some cost standards recommended by IHI for Livingston on outfitting items are given in Table T1-4. This table exemplifies the cost standards that can be developed by using the experience of knowledgeable people combined with historical data. Figure 1-74 illustrates the use of cost standards in the determination of budgets for building a module.

## USES OF COST STANDARDS

The information obtained from process standards and cost standards may be used to construct charts on each unit, similar to the information as illustrated below:

| UNIT | SIZE | WEIGHT (TON) | WELD LENGTH | | MANHOUR | | | DAY | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AWL | MWL | PANEL | FIT | WELD | 1 | 2 | 3 | 4 | 5 | 6 |
| 101 (T) | 40'x12' | 39.8 | 80' | 140' | 75H | 70H | 185H | 4W | 4M | 6W | 6W | 6W | 6W |
| (B) | 40'x12' | 50.4 | 80' | 105' | 75H | 55H | 160H | W | | | 4W | 5W | |

Symbol Explanations:

Fitting — MWL = Welding Length by Manual Process

Welding — AWL = Welding Length by Automatic Process

Panel Joining — T = Top Panel

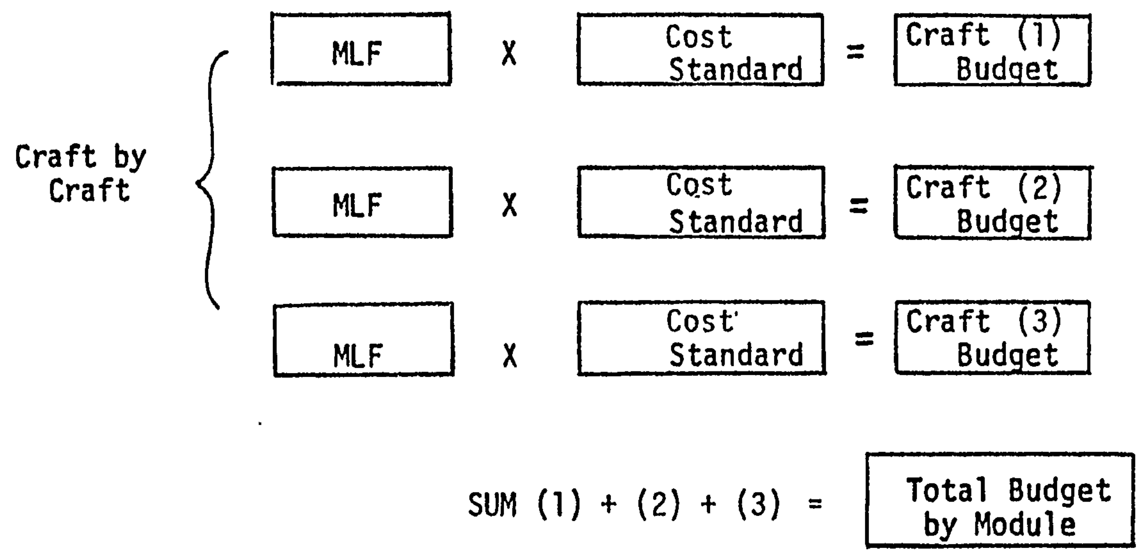
WL = Welding Length — B = Bottom Panel

H = l-fours (Manhours) — W = Workers (Fitters, Welders)

TABLE T1-4

EXAMPLES - COST STANDARDS

| Work Description | Cost Standard |
|---|---|
| Slab layout | $5^H$ per module |
| Foundation setting | $3^H$ per piece |
| Machinery setting | $8^H$ per machinery |
| Prefabricated pipe fitting<br>(less than 60 lb)<br>(over 60 lb) | <br>$2^H$ per piece<br>$3^H$ per piece |
| Valves<br>(less than 60 lb)<br>(over 60 lb) | <br>$1.5^H$ per piece<br>$2.5^H$ per piece |
| ⋮ | ⋮ |




BUDGET CALCULATION BY MODULE

FIGURE 1-14

At this point, final decisions are made concerning the assignment of units to designated gates. Consideration of such items as area of slab required (due to size of the unit) and amount of work required (for conversion from manhours to manpower) is involved. Workloads can then be leveled to accomplish jobs by priority and within gate capabilities.

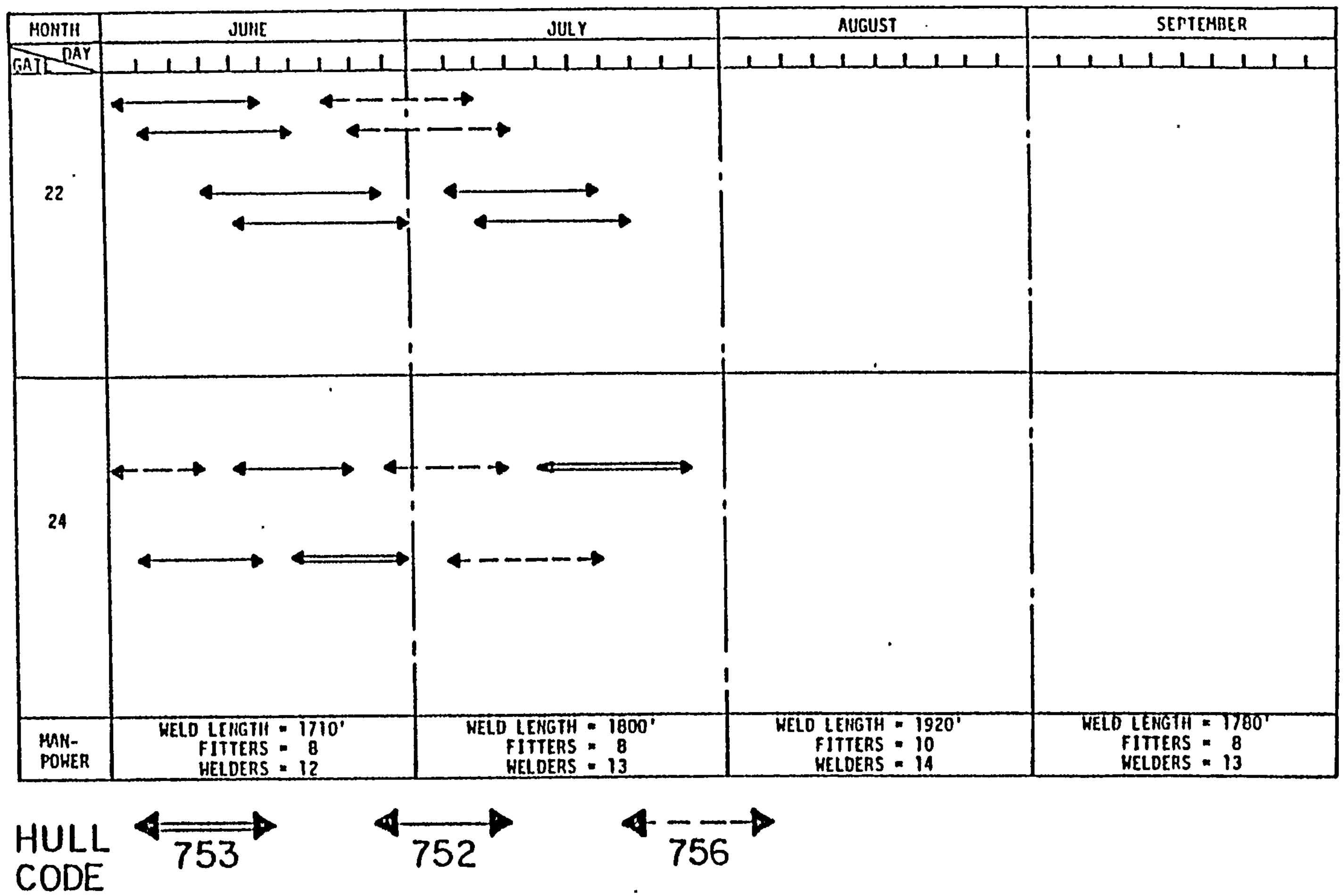
These data are converted to long-term schedules (See Example-Figure 1-15) and short-term schedules (See Example - Figure 1-16). The long-term schedule, covering a four-month period, accounts for production of each hull under construction. The short-term, thirty-day schedule, emphasizes the operations being performed on each unit at each. gate.

A detail schedule can be issued for each assembly unit from this standard data. An example of such a schedule is shown as Figure 1-17. This schedule specifies the work performed to accomplish the fitting, welding, panel joining, and final assembly of the unit.

## SCHEDULING APPLICATIONS

Figure 1-18 presents the hierarchy of schedules developed from the primary master schedule. The Ship Construction Master Schedule is the top-level construction schedule for all work in a given yard. This schedule is prepared by the Production Control Group of the shipyard through an estimation of the required manhours per month based on the throughput rates established for the yard facilities and work force.

Master Schedules are next developed for Erection, Assembly and Outfitting stages for use as guidelines in developing the more detailed subschedules at each process stage.

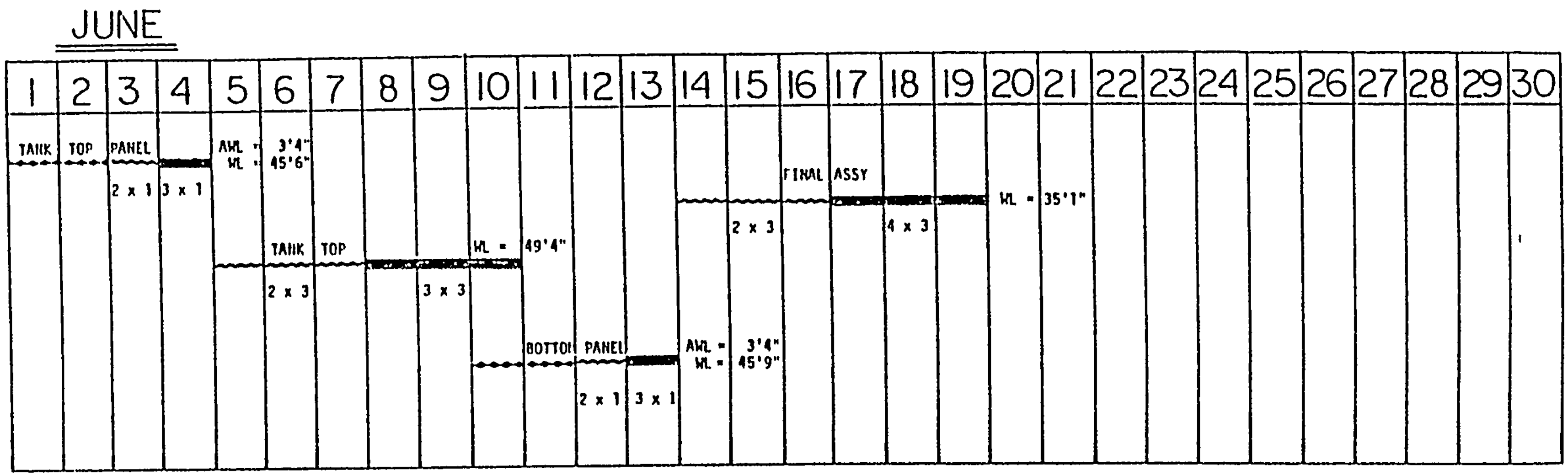



LONG TERM SCHEDULE (SAMPLE)

FIGURE 1-15

| GATE | UNIT | SIZE | WEIGHT | WELD LENGTH | | MANHOURS | | | | | | | | | | | | | | | | | | | | | | | | | | JULY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | AWL | MWL | FIT | WELD | 2 | 3 | 4 | 5 | 6 | 9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 | 19 | 20 | 23 | 24 | 25 | 26 | 27 | 30 | 1 | 2 | 3 | 4 |
| | 101 | 40'x 15' | 50.6 tons | 80' | 170' | 75H | 180H | | | | FIT | | | | WELD | | | | OUTFIT | | | | INSPECT | | PAINT | | | | | ERECT | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

FIGURE 1-16 SHORT TERM SCHEDULE (SAMPLE)




## LEGEND

- PANEL JOINING
- FITTING
- WELDING

**TOTALS**

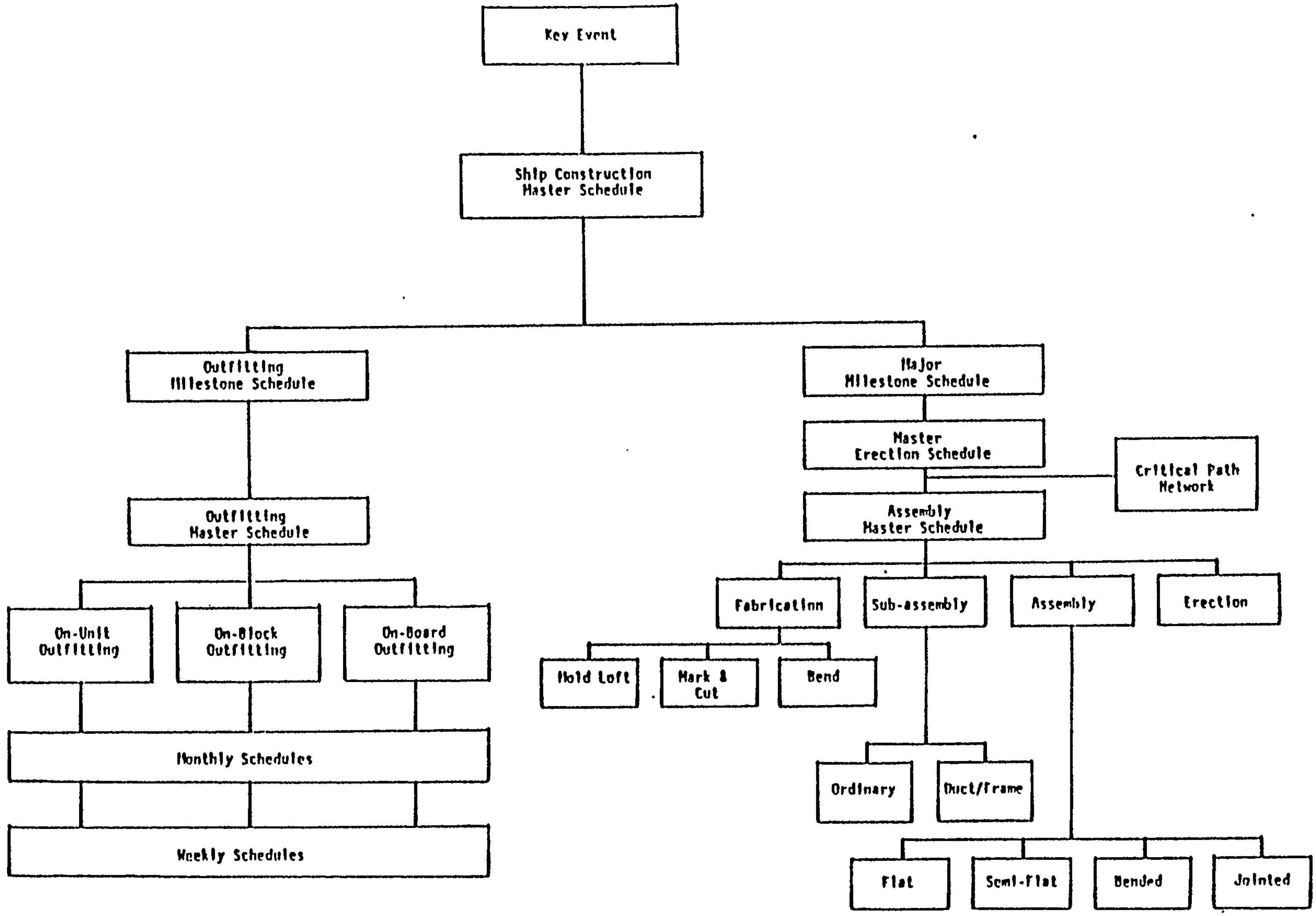
| | |
|---|---|
| AWL (AUTOMATIC WELD LENGTH) | = 6'8" |
| WL (MANUAL WELD LENGTH) | = 175'10" |
| FITTING MANHOURS | = 128 HR |
| FITTING EFFICIENCY | = 1.4 FT/HR |
| WELDING MANHOURS | = 218 HR |
| WELDING EFFICIENCY | = 0.8 FT/HR |

MANNING (EXAMPLE):

2 x 1 MEANS 2 WORKERS FOR 1 DAY

DETAIL SCHEDULE (SAMPLE)

FIGURE 1-17




HIERARCHY OF SCHEDULES

FIGURE 1-18

The Erection Master Schedule is the first working schedule prepared. This schedule establishes the erection times for each unit in each zone of the ship.

The assembly Master Schedule is prepared to show the time requirements for each unit during the assembly process. Each type of unit is sorted by the type of fabrication process required for its production.

The number of required assembly days for the different types of units is a standard in the yards. This standard is shown in Figure 1-19. Also, the calculation of manloading is standardized through the computation of weld deposit required on the various units.

## LIVINGSTON APPLICATIONS

The application of the IHI cost standards program first requires initiation of a corresponding system of process standards. A good process standards program provides a systematic approach for establishing document-ing, and issuing standard work methods to the proper people. This is a necessary pre-requisite to implementation of an effective cost standards program through which the performance of standardized processes are measured and reported in terms of throughput rates and efficiency.

Particular emphasis is placed on the employment of process standardiza-tion techniques in the assembly functions, where written procedures and guidelines are issued for each typical unit of the hulls under construction.

IHI recommended the use of welding length as the control parameter for measuring performance standards, and subsequent calculation of cost standards.

At Levingston the flat panel line is a likely candidate for institution of standards based on measured welding lengths. This assembly shop performs

| PART | UNIT | ASSEMBLY | JOIN |
| --- | --- | --- | --- |
| FORE | Curved Skin | 8 | |
| | Semi-Flat | 7 | |
| | Pre-Ere. | | 15 - 20 |
| MID | Bottom | 7 | 7 - 10 |
| | Skin | 7 | 7 - 10 |
| | Bilge | 7 | 10 - 15 |
| | T. Bhd. | 6 | |
| | L. Bhd. | 6 | |
| | Deck | 6 | 10 |
| E/R | Engine Bed | 8 | 10 - 20 |
| | Curved Skin | 8 | |
| | Semi-Flat | 7 | |
| AFT. | Curved Skin | 8 | |
| | Semi-Flat | 7 | |
| | Pre-Ere. | | 15 - 20 |

REQUIRED ASSEMBLY DAYS STANDARD PER HULL STRUCTURAL TYPE

FIGURE 1-19

work of a routine, repetitive nature for which a direct relationship exists between manhours (of fitters and welders) and welding length.

Conversion from unit weight: This method proposed by IHI has merit as due to its simplistic formula calculation made from available data. However, the data requires verification through analysis of a shipyard's actual performance over a series of like vessets. Since Levingston has completed only the first F-32 type bulker at this time, the data has not been collected nor verified for application of this method. It is believed, however, that this method can have considerable value as a tool for calculating performance standards and cost standards.

The location of work influences its efficiency and productivity. At IHI, assembly is performed in covered shops under controlled conditions. At Levingston, this work is performed both in the shop (Flat Panel Line) and on slabs outside. The measured welding length method, therefore, is applicable to the Panel Line while conversion coefficients; less accurate but easier to obtain, are more appropriate to assembly work on slab.

In the Fabrication area, IHI recommended piece counts and tonnage as parameters for Levingston to use. Work orders issued at Levingston are written to correspond to the process gates through which a unit passes. Since manhours are charged against these work orders, Levingston plans to collect this data and use it as a basis for projecting efficiency on future work of a similar type. This is the method that has been employed successfully by the Japanese and is applicable to U. S. shipbuilding activities.

CONCLUSION

The main objective of the calculation of performance standards is for use in projecting accurate plans and schedules. The data collection methods proposed by IHI are planned for implementation at Levingston when a sufficient data base has been compiled. Probably the single most important factor in providing a system of useful performance standards is assuring that accurate data is reported. The standards are only as reliable as the data upon which they are based. This depends on accurate reporting by supervision and validated calculations by people knowledgeable of the processes and methodology of technical analysis.